Analysis of Lateral Transverse Modes of Ridge-Geometry AlGaInN Laser Diodes

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Abstract

The analyses of the threshold current densities and the lateral far field patterns(FFPs) of ridge-geometry AlGaInN laser diodes(LDs) are demonstrated. Some obtained results of the ridge-geometry LDs are also reported.

Fig. 1 is a schematic structure of ridge-geometry AlGaInN LD. An atmospheric pressure metalorganic chemical vapor deposition system was used to grow AlGaInN compound semiconductors. A c-plane sapphire wafer with slight misorientation(0.1-0.2degrees) was used as the substrate. The misorientation angle was selected to obtain a steplike surface morphology of a GaN layer and an uniform electroluminescence image of a light emitter[1]. The LD structure consists of a 0.03μm-thick GaN buffer layer, a 3μm-thick n-GaN layer, a 0.04μm-thick $In_{0.07}Ga_{0.93}N$ layer, a 0.6μm-thick n-$Al_{0.1}Ga_{0.9}N$ cladding layer, a 0.1μm-thick n-GaN guiding layer, a 67nm-thick active layer(λ=405-410nm) composed of $In_{0.15}Ga_{0.85}N/In_{0.05}Ga_{0.95}N$ 5-period quantum-well structures, a 18nm-thick p-$Al_{0.18}Ga_{0.82}N$ layer, a 0.1μm-thick p-GaN guiding layer, a 0.33μm-thick p-$Al_{0.1}Ga_{0.9}N$ cladding layer, a 0.1μm-thick p-GaN contact layer. After the growth, ridge structure was formed using a reactive ion etching system. The outside of the ridge portion was buried with SiO_2. The mirror facets were formed by cleaving methods and the cavity length was 0.5mm.

Fig.2 shows the dependence of the threshold current density(Jth) under the pulse current condition on the ridge dimension. The two sets of measured data correspond to LDs with the ridge width(W) of ~1.8μm (1.75-1.84μm) and LDs with the ridge width of ~2.3μm(2.25-2.42μm), The horizontal axis t_O is the total thickness of the p-GaN guiding layer and p-$Al_{0.1}Ga_{0.9}N$ cladding layer outside of ridge portion as shown in Fig. 1. The threshold current density is almost constant for the t_O smaller than ~0.1μm,, while it increases rapidly for t_O over 0.2μm. Solid curves in Fig.2 are the calculated lateral optical confinement factor of the fundamental mode($\Gamma_{//}$). In the calculations, we ignore the effects caused by current injection, for example gain guiding effect. The calculated lateral optical confinement factor is over 0.95 for the t_O smaller than ~0.15μm, while it decreases rapidly for the t_O over ~0.2μm. From these results, it is found that the change of threshold current density can be explained by the lateral confinement effect of the ridge structure and the t_O should be smaller than 0.2μm for sufficient lateral confinement($\Gamma_{//}$~1) for the W of ~2μm. Some examples of lateral FFPs of the ridge-geometry LDs are demonstrated in Fig.3 with values of full angle between half power points($\Theta_{//}$s). As shown in Fig.4, these measured $\Theta_{//}$s are relatively correspond to calculated values, especially in case that the $\Theta_{//}$ is over ~7 degrees, or a calculated lateral index step(Δn) is over ~4E-3. It is important to consider and control the ridge

dimensions in order to realize LDs with low threshold current and demanded optical characteristics.

We also demonstrate the ridge-geometry AlGaInN LD with output power of 40mW at a current of 160mA and a voltage of 7V under CW operation. The threshold current was 60mA and any kinks weren't observed up to 47mW. The ridge dimensions were the W of 1.7μm and the t_O of 0.14 μm. The HR coating consisting of 4 pairs of TiO_2/SiO_2 was formed on the rear facet. The $\Gamma_{//}$ of 0.96 and the $\Theta_{//}$ of 7.3 degrees were estimated by the calculations and the measured $\Theta_{//}$ was 8 degrees under the pulse condition.

[1]T. Yuasa, Y. Ueta, Y. Tsuda, A. Ogawa, M. Taneya and K. Takao, Jpn. J. Appl. Phys. Vol.38(1999)L703.

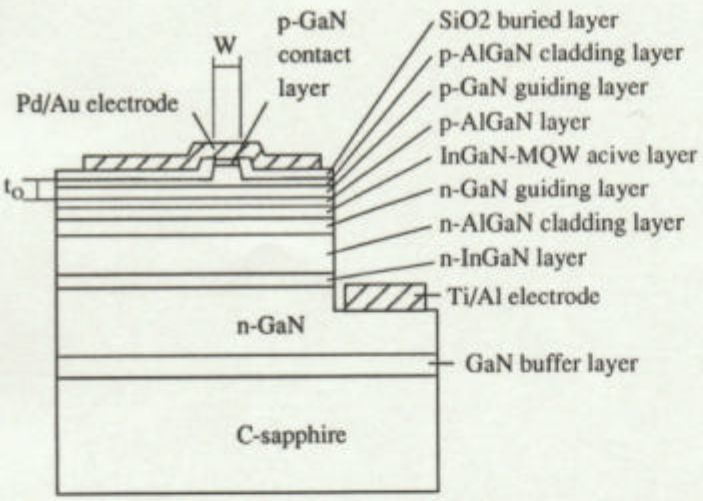

Fig.1. The schematic structure of ridge-geomety AlGaInN LD.

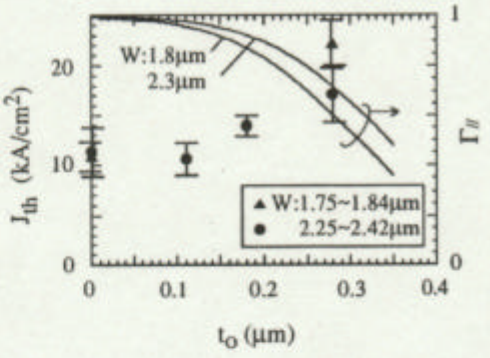

Fig. 2. Dependence of threshold current density(Jth) on ridge dimensions. Solid curves are calculated functions of lateral confinement factor ($\Gamma_{//}$).

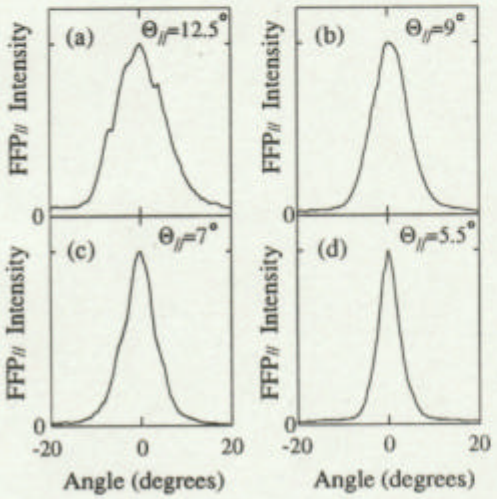

Fig.3. Lateral FFPs of the ridge-geometry LDs.
(a)W=1.84μm, t_O=0.00μm (b)W=2.23μm, t_O=0.11μm
(c)W=1.61μm, t_O=0.18μm (d)W=1.75μm, t_O=0.28μm

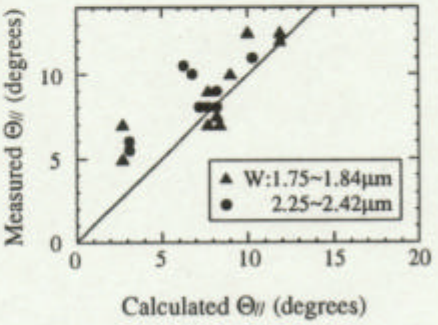

Fig. 4. Measured and calculated values of full angle between half power points in lateral FFP($\Theta_{//}$).